Drought and Wildland Fire: Searching for Practical Solutions

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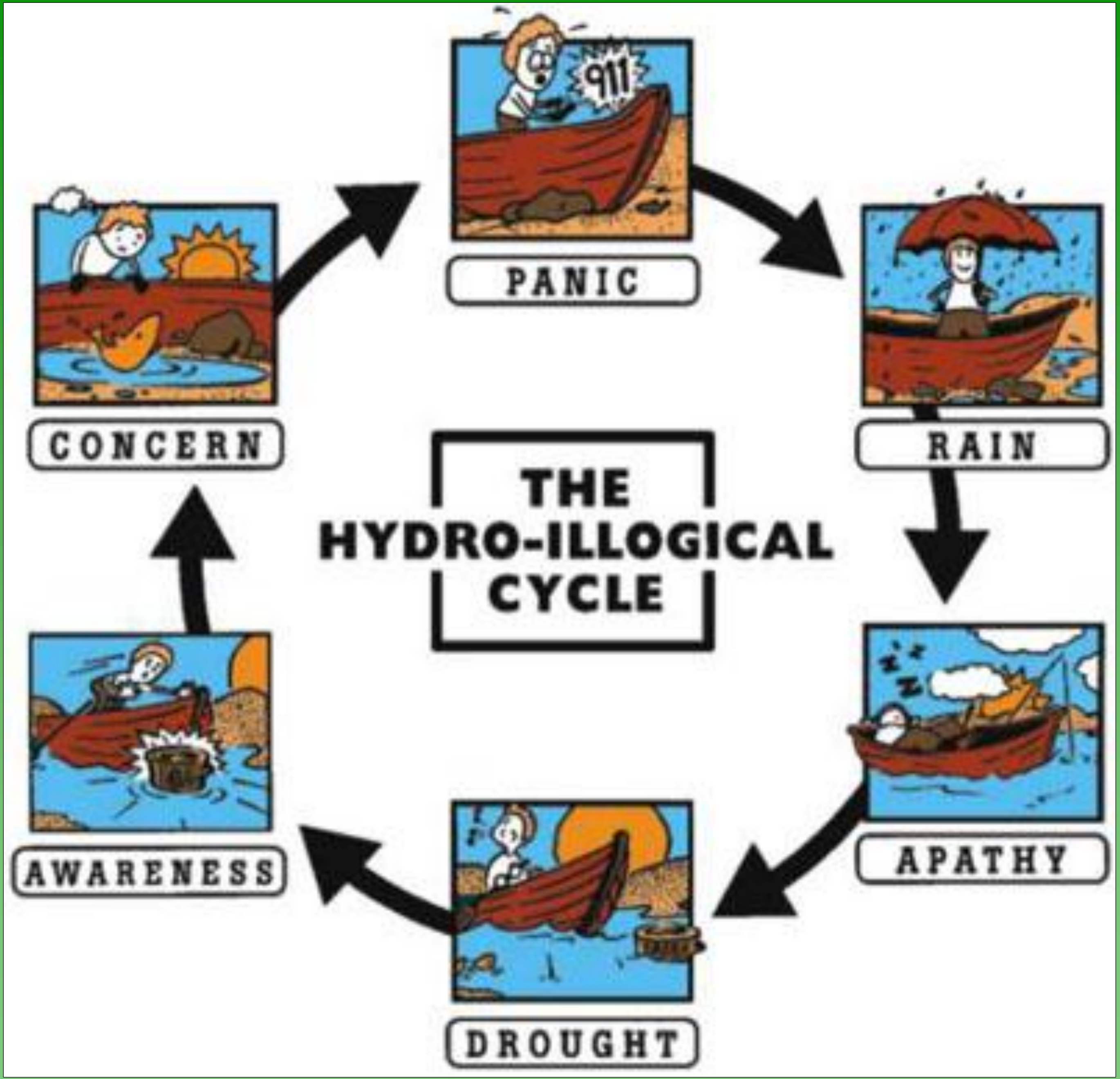
It is well understood that the incidence and behavior of forest fire depends mainly on short-term weather influences of no more than several days duration. And yet, all through the history of fire danger rating in the United States and Canada, runs a persistent interest in the effects of weather over a much longer term, usually studied under the heading of "drought".

C.E. Van Wagner
Drought, Timelag, and Fire Danger Rating -- Paper presented at the 8th National Conference on Fire & Forest Meteorology held at Detroit, Michigan, April 29-May 2, 1985

Wildland fire and drought issues certainly follow this general pattern or cycle as well



Backdrop to Comments

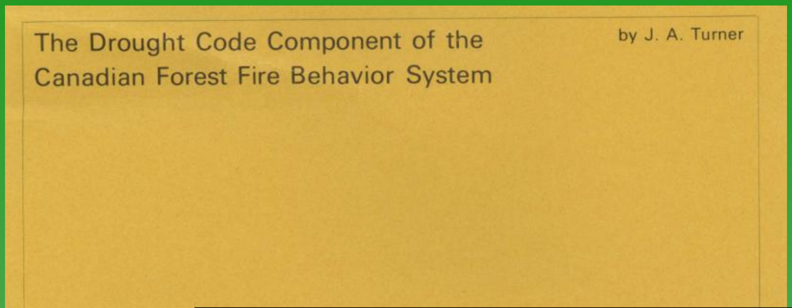
• Thinking of boreal, subalpine, coastal and temperate forests which contain fuel types with substantial organic layers, including peat bogs

• Directed at both environmental research scientists, including graduate students, operations personnel

• Based on involvement in wildland fire since 1971 (CAN, US, NZ, AUS)

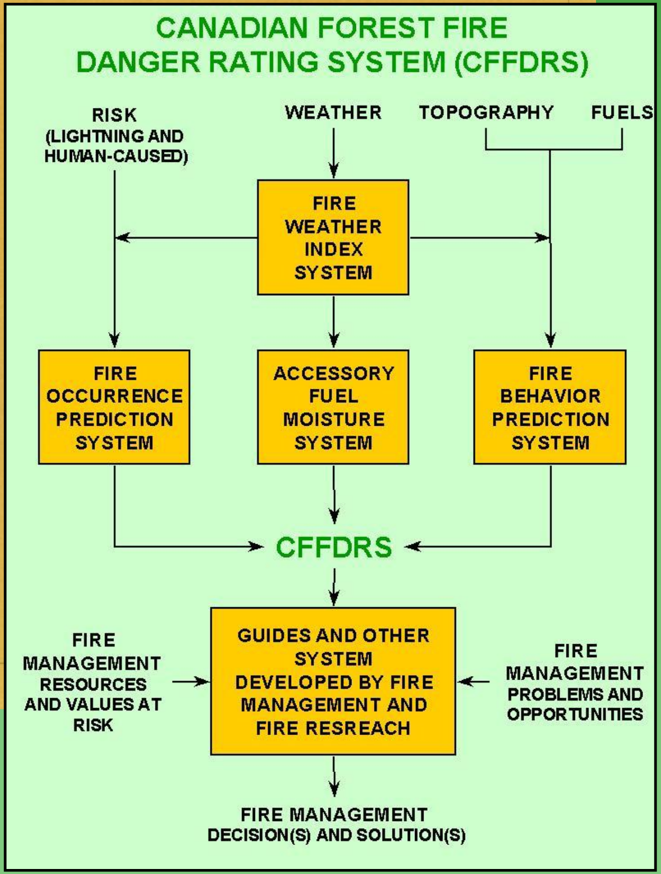
• A text version of this presentation to be posted on the FERIC Wildland Fire Operations Research Group website (http://fire.feric.ca)

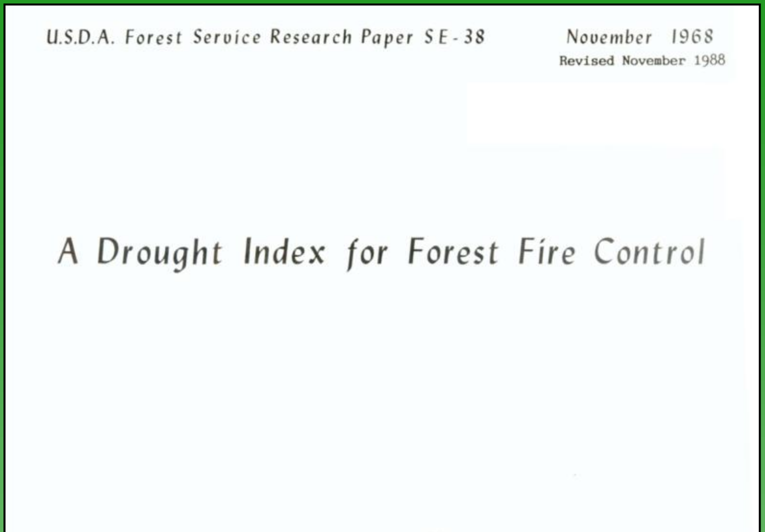
Background Information



The Drought Code Component of the Canadian Forest Fire Behavior System

by J. A. Turner



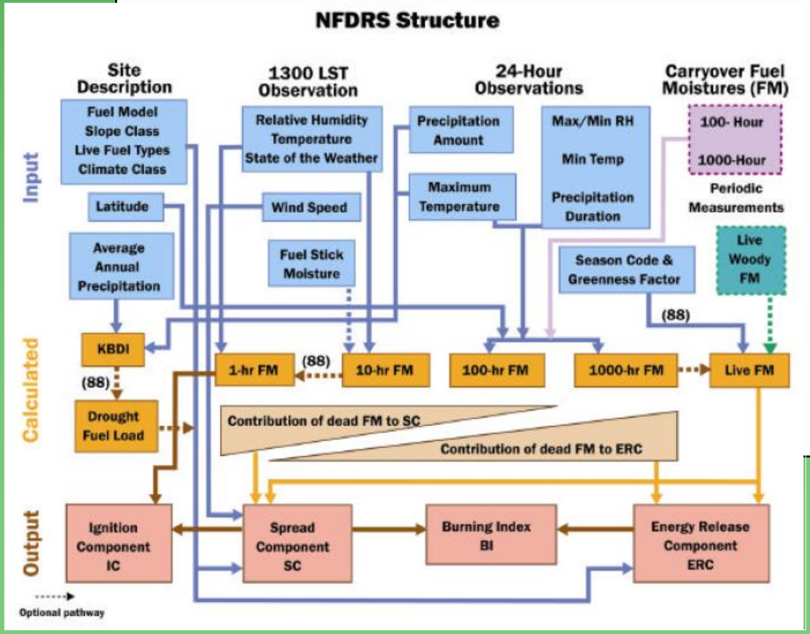


U.S.D.A. Forest Service Research Paper SE-38

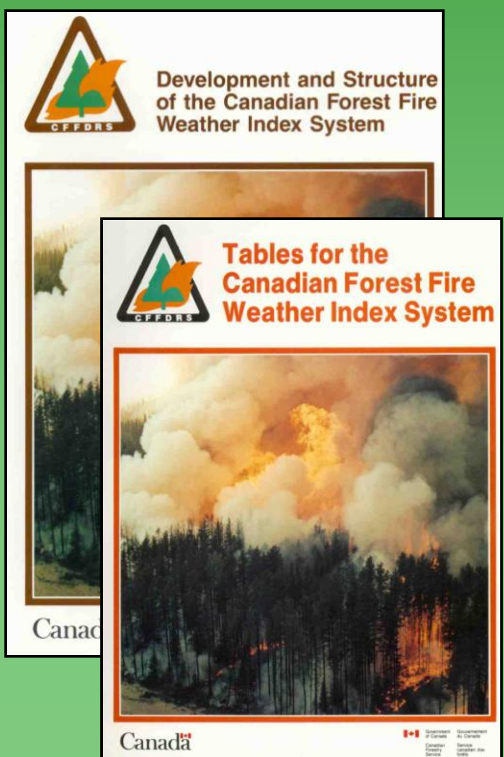
November 1968

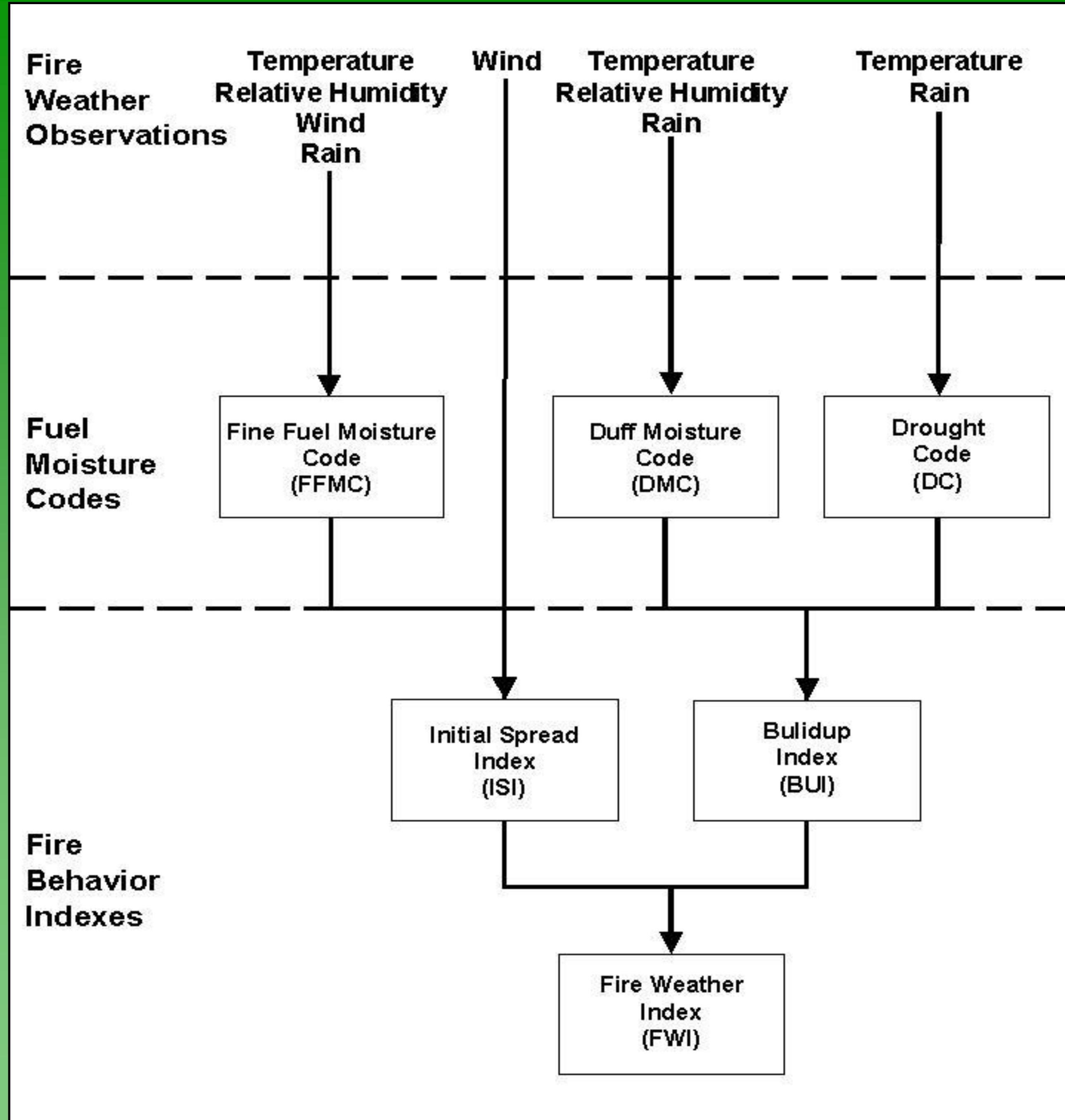
Revised November 1988

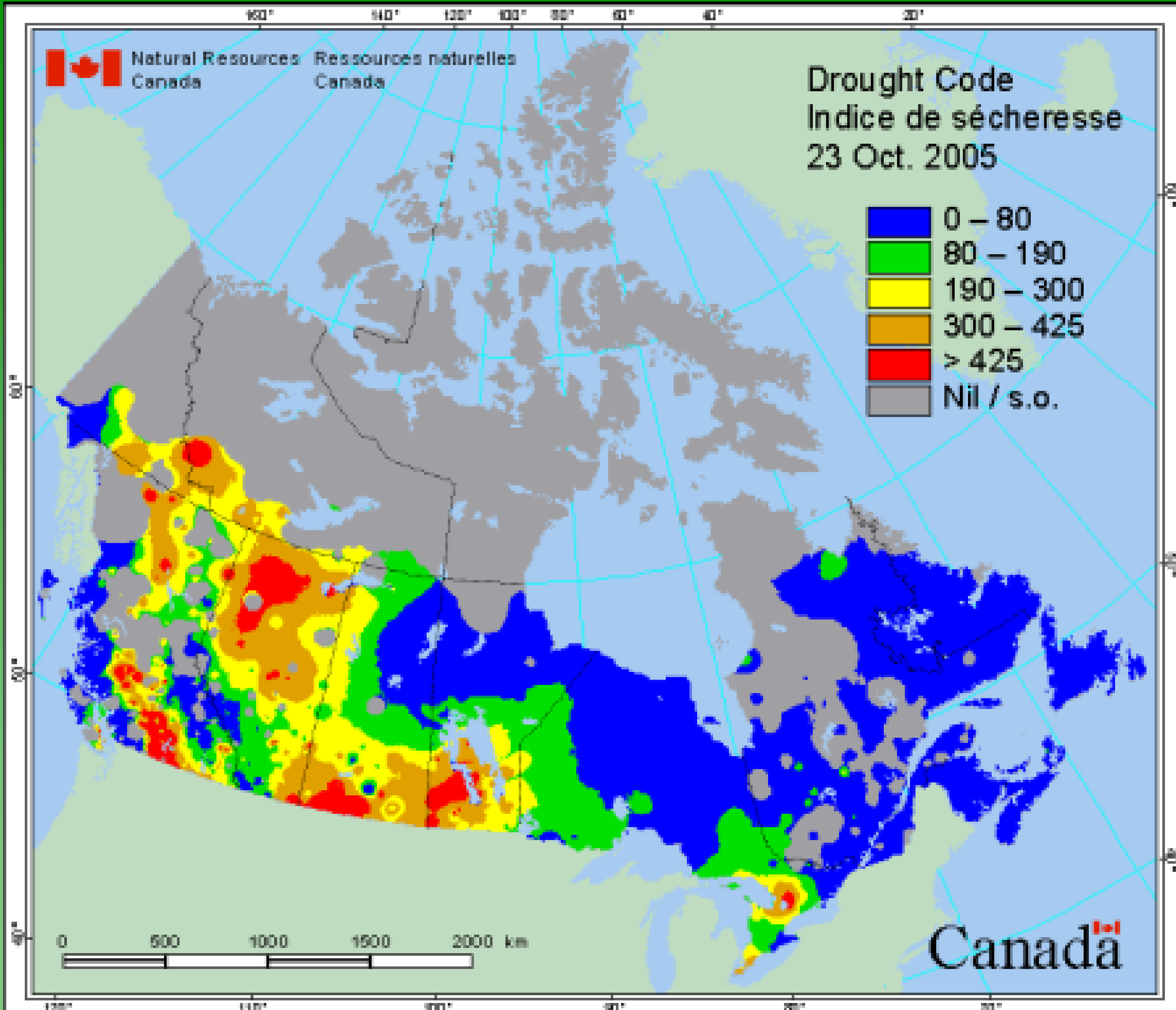
A Drought Index for Forest Fire Control



Structure of the Canadian Forest Fire Weather Index (FWI) System

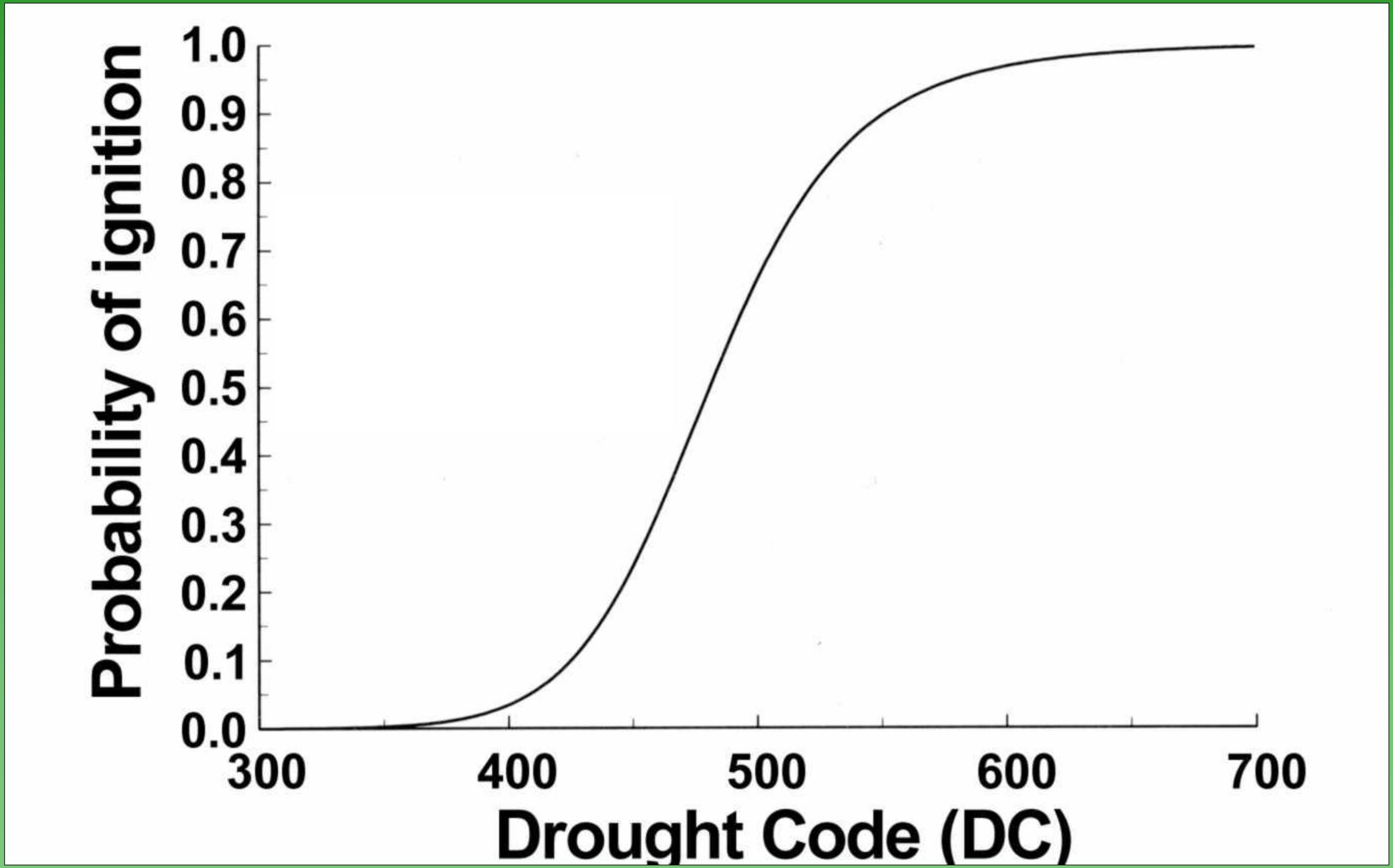






Natural Resources Canada
Ressources naturelles Canada
Drought Code
Indice de sécheresse
23 Oct. 2005
0 – 80
80 – 190
190 – 300
300 – 425
> 425
Nil / s.o.
0
500
1000
1500
2000 km
Canada

Probability of Sustained Smoldering Ignition as a Function of the Drought Code in Lower Feathermoss Layers (5-25 cm in depth)



Many "rules of thumb" also exist (e.g., DC > 300)

Flow chart of spring Drought Code (DC) starting value determination

Fall DC value and date of last calculation

↓

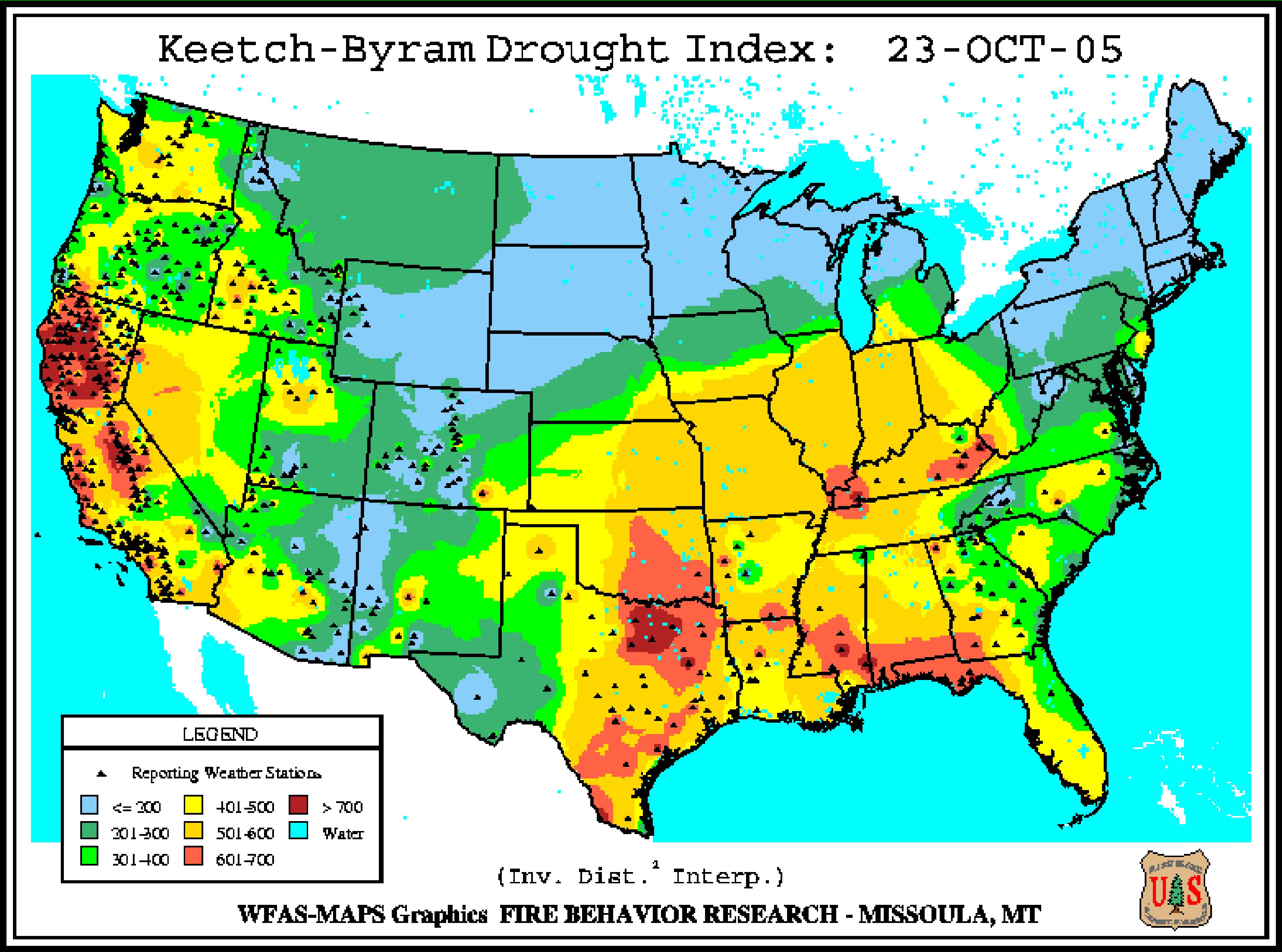
Keep record of cumulative precipitation amount for the period between date of last DC calculation the previous fall and spring starting date of calculations.

↓

Select values for Carry-over Fraction of Fall Moisture and Precipitation Effectiveness Fraction.

↓

Determine spring DC starting value based on fall DC, Total Overwinter Precipitation (mm water equivalent)



Keetch-Byram Drought Index: 23-OCT-05
LEGEND
Reporting Weather Stations
<= 200
201-300
301-400
401-500
501-600
601-700
> 700
Water
(Inv. Dist.² Interp.)
WFAS-MAPS Graphics FIRE BEHAVIOR RESEARCH - MISSOULA, MT

KBDI Interpretation Guidelines

Keetch-Byram Drought Index Revisited: Prescribed Fire Applications

Mike Melton

In volume 50, number 4, of *Fire Management Notes*, I contributed an article about the Keetch-Byram Drought Index (K-BDI), its relationship to fire suppression, and the problems that could be expected with suppression efforts at different levels of drought as measured by the index. Since that time, it has received many inquiries and comments appreciative of the practical information contained in the article. It has also been used as a training tool in a variety of fire management classes. I also learned that some wildland fire managers, especially in the Southeastern United States, have used the information found in the original article and applied it to prescribed burning. While the information contained in the original article is applicable to prescribed fire, there are some differences. With prescribed fire practitioners in mind, in this article I have expanded and addressed the K-BDI specifically from a prescribed fire perspective.

Keetch-Byram Drought Index (K-BDI) levels are calculated as part of the 1988 revisions of the National Fire-Danger Rating System (NFDRS) (Burgan 1988). Since the K-BDI calculations are simple, they are often made and kept by individuals or field offices that do not have access to NFDRS calculations or are not near an office that does.

Mike Melton is a district ranger, USDA Forest Service, Daniel Boone National Forest, Stearns Ranger District, Whitley City, KY.

Drought indexes are not designed to measure fuel moistures, rather they indicate environmental conditions that affect fuel profiles.

To calculate the K-BDI values, users need a copy of the directions found in the original documentation (Keetch and Byram 1968) and a rain gauge. Then a simple mathematical process is necessary to determine the K-BDI value on a daily basis.

In the following discussions, I have addressed the index and effects on a drought scale difference of 200, which corresponds to the loss of 2 inches (5 cm) of water from the fuel and soil profile as the drought progresses from one stage to the next.

These following discussions are based on the fact that the seasonal variations in the index generally follow the southern seasonal temperature pattern. The index will be low in the winter and spring, increase during the summer and early fall, and taper off again in winter. In my conclusion, I discuss some of the variations found when the index departs from normal, some things to be expected from rising and falling indexes, and the days-since-rain concept.

K-BDI Levels 0-200

Much of the understory prescribed fire work in the South is done at the 0 to 200 levels, which correspond to the early spring dormant season conditions following winter rains. Soil moisture levels are high, and fuel moistures in the 100- and 1,000-hour fuel classes are sufficiently high, so these larger fuel classes do not significantly contribute to prescribed fire intensity in most cases.

Fuel moistures in the 1- and 10-hour classes will vary daily with environmental conditions. On any particular day, prescribed fires should be planned based on the predicted levels of moisture within these two fuel classes in association with weather conditions. Prescribed fire planners should be aware that areas with heavy loadings of these two smaller fuel classes can exhibit intense behavior resulting from the amount of fuel to be consumed. Also, areas that are influenced by slope and aspect can experience erratic and intense fire behavior from the preheating effects. Southern aspects can produce intense fire behavior while northern aspects of the same unit may have difficulty carrying the fire.

At the 0 to 200 levels, nearly all soil organic matter, duff, and the associated lower litter layers are left intact. These layers, even though they may not be soaking

Continued on page 8

The Keetch/Byram Drought Index: A Guide to Fire Conditions and Suppression Problems

Mike Melton

District ranger, USDA Forest Service, Daniel Boone National Forest, Stearns Ranger District, Whitley City, KY

The 1988 version of the National Fire Danger Rating System (NFDRS) has been completed and should be operational by the first part of 1991. The NFDRS has an important new addition: The Keetch/Byram (K/B) Drought Index calculations have been added to the system. As a part of the NFDRS, the K/B index will be the most widely used drought index for fire danger rating. Fire personnel will need to know specifically the effect of drought on both wildfire and prescribed fire and the significance of the index and its relationship to the fire environment. This means fire managers must understand the K/B index system, be able to interpret the data from the system, and apply that knowledge to the local fire situation.

The K/B Index

John Keetch and George Byram developed the K/B index at the Southern Forest Fire Laboratory to evaluate the effects of long-term drying on litter and duff and subsequently, on fire activity (1968). The index is based on a measurement of 8 inches (0.2 m), of available moisture in the upper soil layers that can be used by vegetation for evapotranspiration. The index measure is in hundredths (0.01) of an inch of water and has a range of 0 through 800, with 0 being saturated and 800 representing the worst drought condition. The index indicates deficit inches of available water in the soil. A K/B reading of 250 means there is a deficit of 2.5 inches (6.4 cm) of ground water available to the vegetation. As drought progresses, there is more available fuel that can contribute to fire intensity.

Fire Behavior at Selected K/B Levels

The following information is a compilation of data and observations fire managers and I have made from field observations of both wild and prescribed fire at numerous locations. It is an attempt to qualify and quantify in common terms the effect of continued drought on forest fuels and the problems arising from drought conditions during the course of wildfire and prescribed burns. This information should help fire practitioners to more fully understand the relationship between the K/B index readings—which indicate the extent of drought—and the fire environment.

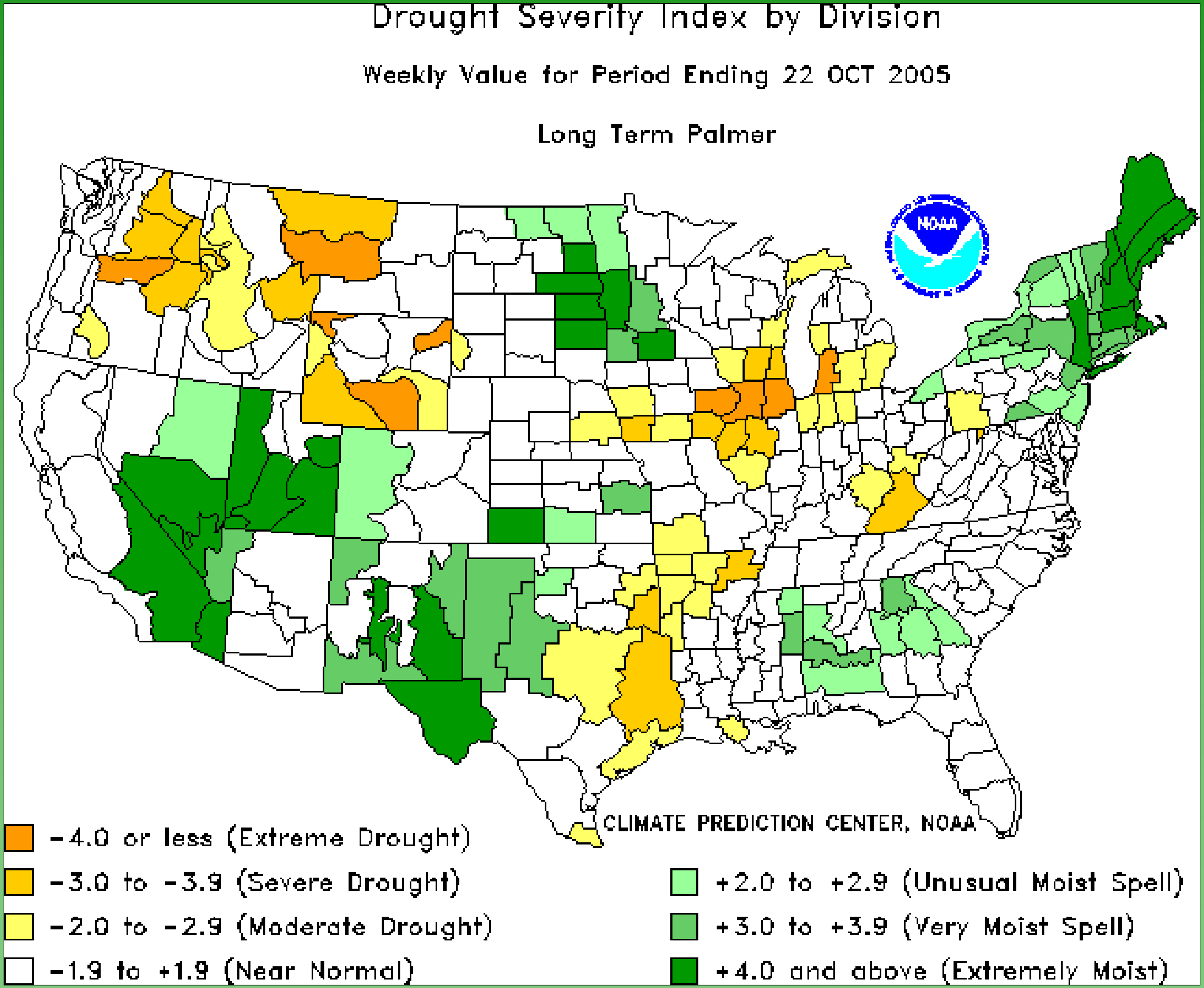
As a part of the NFDRS, the K/B index will be the most widely used drought index for fire danger rating.

The effect of drought on fire behavior will vary between fuel types and topographic regions. Mountainous hardwood fuels will react differently than the Southern pine fuels to drought and consequently fire effects will also differ. Rain or relative humidity and wind may also require an adjustment to K/B level interpretation. For instance, even if the K/B level is extremely high, a brief rain will temporarily render fuels incapable of burning. Yet on the other hand, the K/B index can be low (<100) and high wind and low relative humidities can create an extreme situation in some fuel types. The following descriptions of conditions at various K/B levels is primarily related to the Southern Coastal Plain and Piedmont regions, but these can be considered applicable in many areas of the country. Fire personnel should remember that specific situations may be different than those described and should use this information to complement his or her experiences at a particular location.

K/B Levels 0–150. During this stage of drought, the fuels and ground are quite moist. Fine fuels exhibit daily drying, burning readily at times but also recovering to a high moisture content at night. This level is ideal for winter or spring prescribed burns. Most fires are easily suppressed with normal practices and generally are not a problem. The lower litter and humus layers are moist and not affected by fire. Most fires die out at night due to humidity recovery and its dampening effect on the fine fuels. Some fuel types (grasses) burn actively, but seldom create much problem with control efforts. Generally, extensive mop-up is not required, since most heavy fuels (100 and 1000 h) are too wet to ignite. Ignition of snags is not normally a problem on wild or prescribed fires. The spring fire season can still generate some extremes in behavior on wildfires due to the nature of fine fuels, especially in fuel types with a heavy loading of grasses. Drying is generally limited to the fine surface fuels and the organic layers still retain sufficient moisture to resist burning. This could be considered the business-as-usual period.

K/B Levels 150–300. Within this range, scattered patches of surface

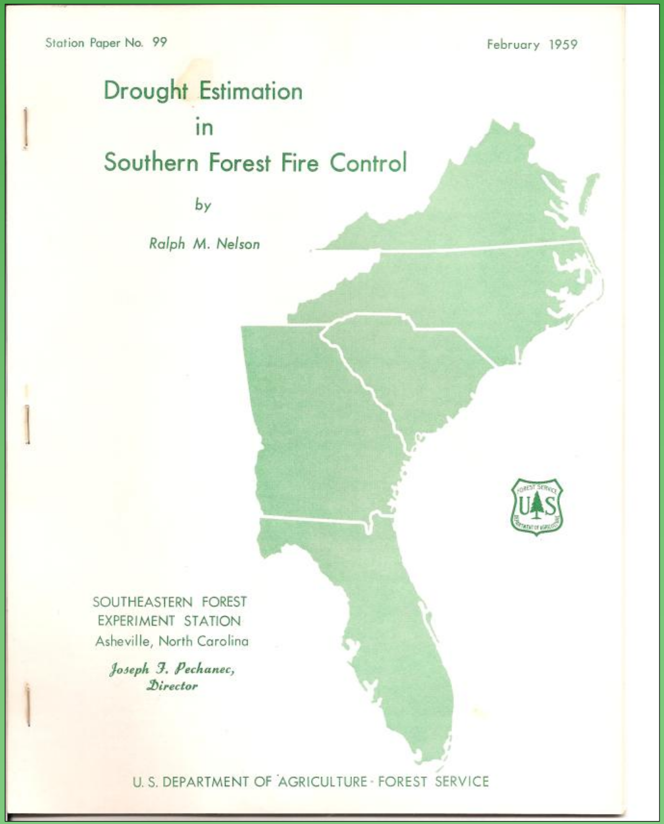
Palmer Drought Severity Index (PDSI) is linked to the U.S. Wildland Fire Assessment System



Thought #1:

A Primer on Drought and Wildland Fires is Needed

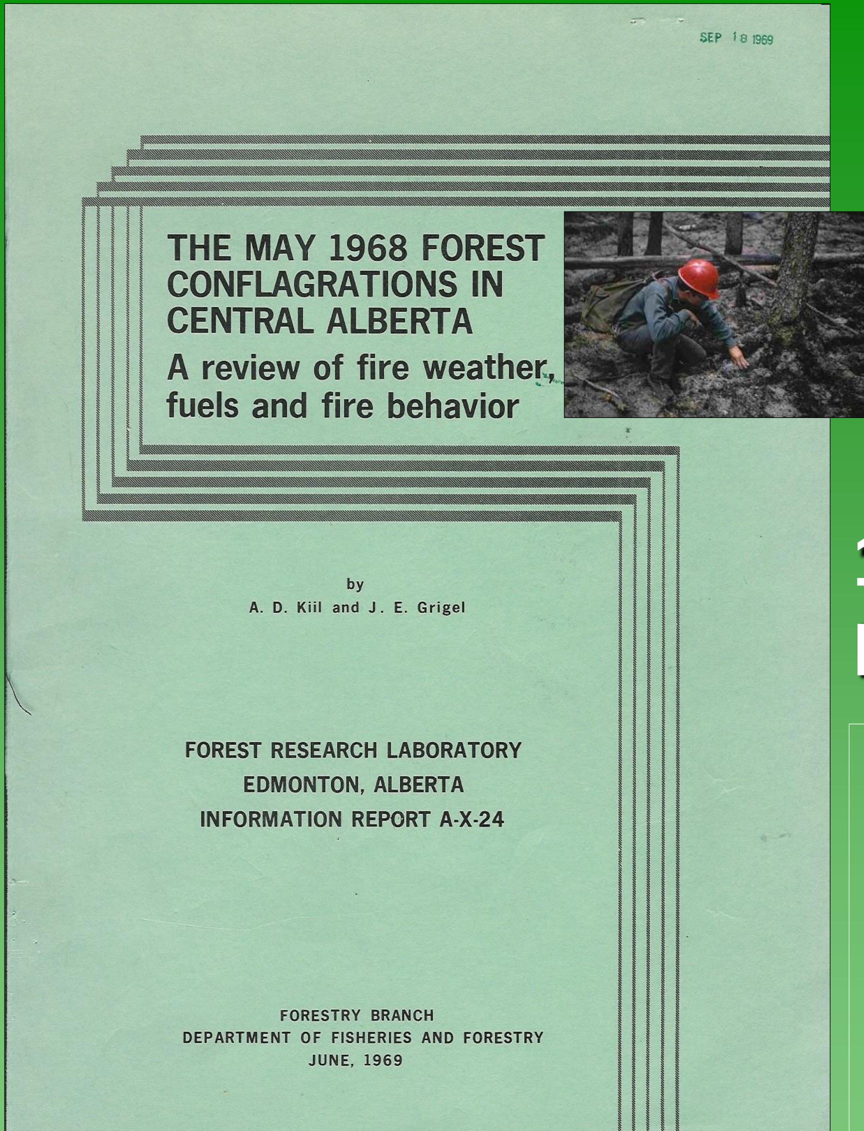
-- i.e., a state-of-the knowledge summary describing the nature and characteristics of drought as it relates to wildland fire incidence and wildland fire control, including clarification of various misconceptions



Popular Misconception about Drought and Wildland Fire

Prolonged drought is a prerequisite for a severe fire event and/or extreme fire behavior.

Major Run of Lesser Slave Lake Fire (65 km in 10 hrs)


SEP 18 1969

THE MAY 1968 FOREST CONFLAGRATIONS IN CENTRAL ALBERTA

A review of fire weather, fuels and fire behavior

by

A. D. Kiil and J. E. Grigel

FOREST RESEARCH LABORATORY
EDMONTON, ALBERTA
INFORMATION REPORT A-X-24

FORESTRY BRANCH
DEPARTMENT OF FISHERIES AND FORESTRY
JUNE, 1969

May 23, 1968

Dry-bulb Temp – 21.1^{o}C

RH – 30%

10-m Open Wind – 46 km/h

Days Since Rain – 16

Fine Fuel Moisture Code (FFMC) – 93

Duff Moisture Code (DMC) – 53

Drought Code (DC) - 245

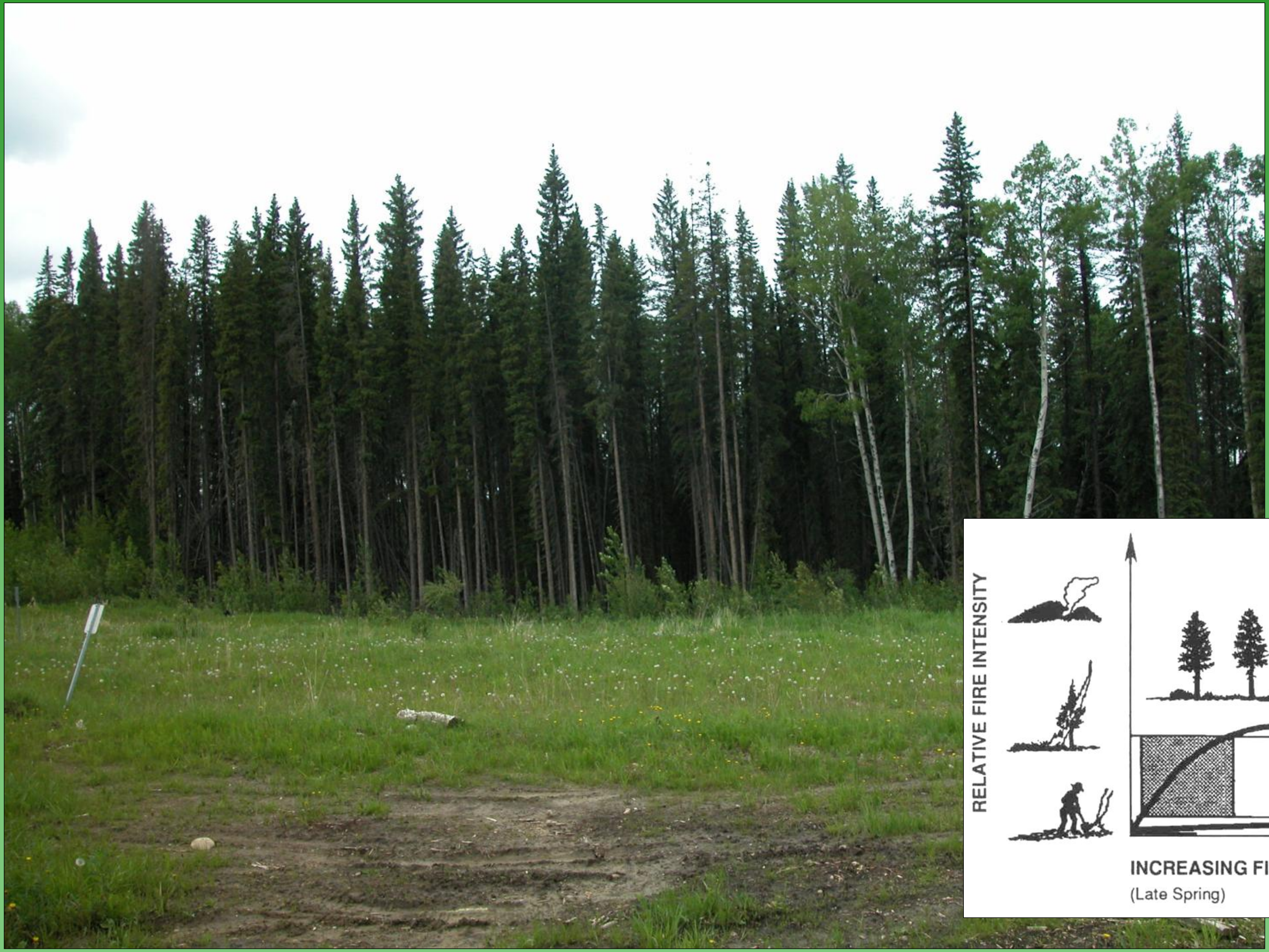
Initial Spread Index (ISI) – 68 Buildup Index (BUI) - 69

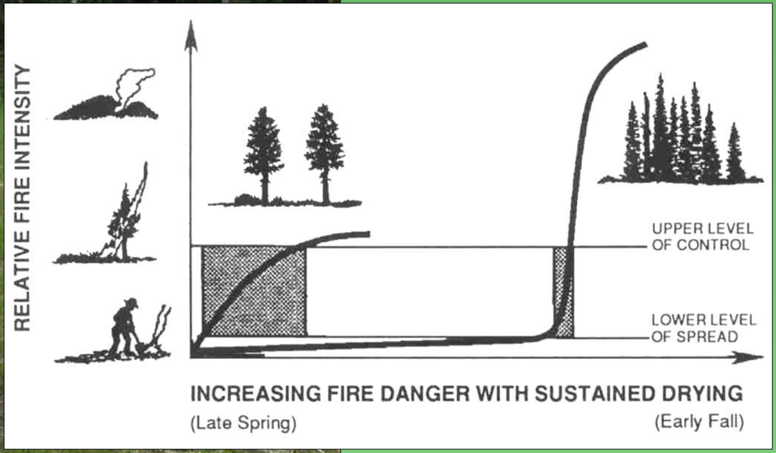
Fire Weather Index (FWI) - 86

Drought can exacerbate the wildland fire situation in a number of ways. For example:

- Reduces surface water availability for fire suppression
- Decreases water table levels thereby impacting upper forest floor moisture contents and what would be considered normal barriers to fire spread
- Increases the probability of a fire occurring because of the sustained smouldering ignition potential in the ground or sub-surface fuels
- Increases the difficulty of containment & mop-up or extinquishment due to fire's persistence
- Large number of suppression resources tied up on mop-up and not available for initial attack

Recognition that Some Fuel Types Need to Undergo Prolonged Drying in Before a Critical Threshold for Large Fire Growth is Possible





Keetch–Byram Drought Index: Can It Help Predict Wildland Fires?

SCITRAN Inc. SCIENCE TRANSFERRED TO APPLICATIONS

GEORGIA FORESTRY COMMISSION

Daniel W. Chan, James T. Paul, and Alan Dozier

The Georgia Forestry Commission uses the Keetch–Byram Drought Index (KBDI) (Keetch and Byram 1968) to determine potential wildland fire hazards. (For an overview of KBDI, see the sidebar.) The objectives of our study were to better understand the relationship between KBDI and fire activities in Georgia and to evaluate KBDI computed from National Weather Service (NWS) observational data compared with KBDI computed from fire weather observations.

What We Did

Traditionally, fire weather observations for determining wildland fire hazards are recorded at 1 p.m. daily. This means that the maximum temperature recorded at this time usually occurs during the previous day's afternoon hours. Likewise, the 24-hour precipitation recorded is from 1 p.m. on the previous day until 1 p.m. on the present day. By contrast, the NWS reports maximum temperature and 24-hour precipitation for the 24-hour period ending at midnight.

To compare NWS data to traditional fire weather data, we used NWS hourly data from Athens Municipal Airport, Macon Regional Airport, and Savannah International Airport from 1957 to1995. From these data, we constructed a fire-weather-type observation for both 1 p.m. and midnight. Then we used the data to calculate a KBDI for the two defined observation times.

Daily records for the 24-hour period ending at 1 p.m. and daily records ending at midnight can yield different maximum temperature and rainfall data for the previous 24-hour period. If a heavy rain incident occurred after 1 p.m., the KBDI numbers from 1 p.m. and

Daniel Chan is a meteorologist for the Georgia Forestry Commission, Macon, GA; James Paul is the President and Chief Scientist for SCITRAN®, Inc., Gray, GA; and Alan Dozier is the Chief of Forest Protection for the Georgia Forestry Commission, Macon, GA.

> Georgia's typical fire season from 1957 to 2000 ran from February through April—when the Keetch–Byram Drought Index was lowest.

What is the Keech–Byram Drought Index?

According to Melton (1989), the Keetch–Byram Drought Index (KBDI) is an index based "on a measurement of 8 inches (0.2 m) of available moisture in the upper soil layers that can be used by vegetation for evapotranspiration.

The index measure is in hundredths of an inch of water and has a range of 0 to 800, with 0 being saturated and 800 representing the worst drought condition. The index indicates deficit inches of available water in the soil. A K/B reading of 250 means there is a deficit of 2.5 inches (6.4 cm) of ground water available to the vegetation. As drought progresses, there is more available fuel that can contribute to fire intensity."

If a location has been dry during the previous 24 hours, the KBDI will increase, depending on the maximum temperature in the previous 24 hours, the previous day's index, and the annual rainfall amount at that location. Generally, high temperature and a low KBDI mean big increments.

When an area has received rain during the previous 24 hours, the index changes, depending on the rain-adjusted KBDI—for each 0.01 inches (0.03 cm) of net rainfall, one point is subtracted from the previous day's index—the maximum temperature, and annual rainfall amount at that location.

We shouldn't expect fire-related drought indices to necessarily correlate well with any measures of fire business.

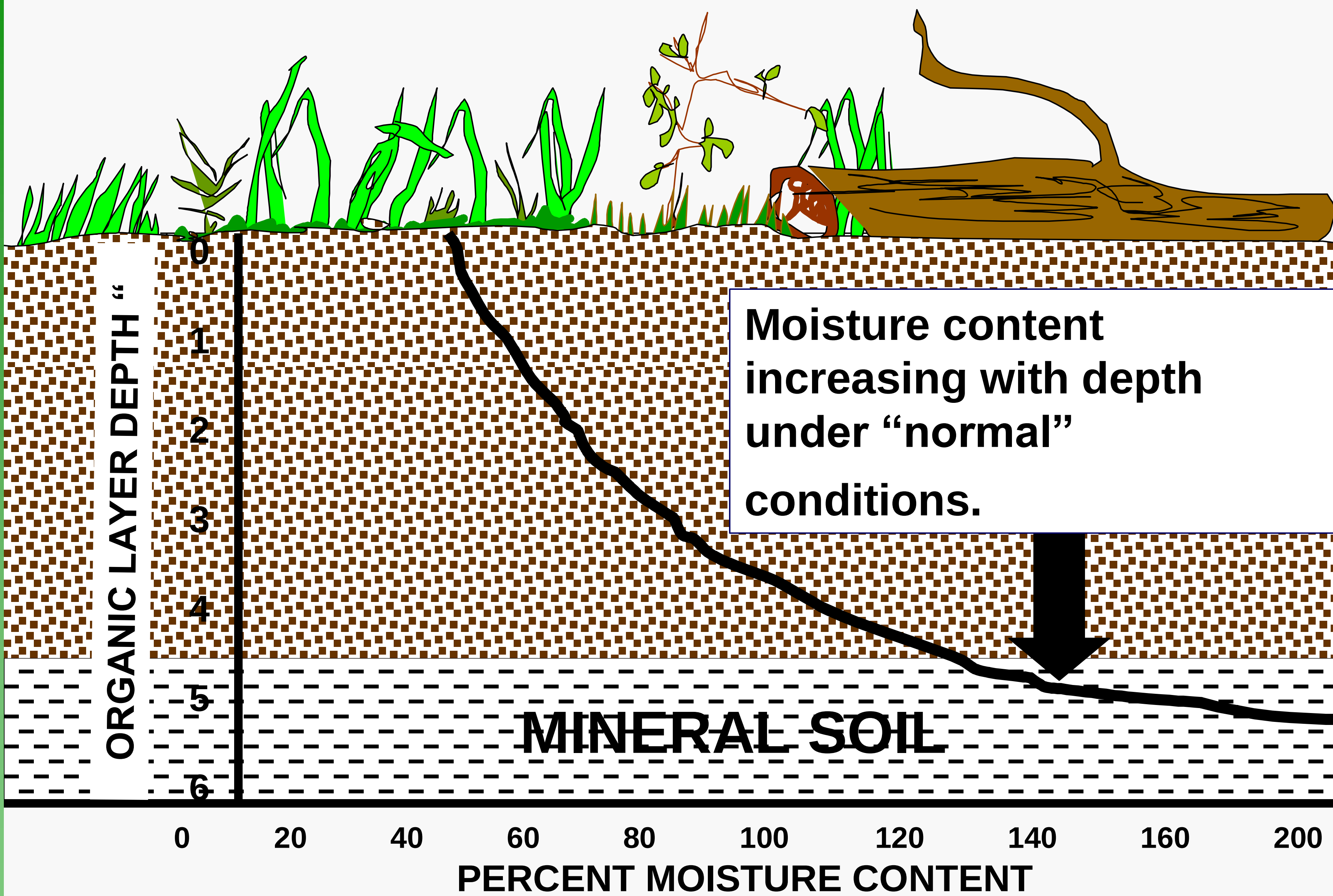
"In Georgia, the Keetch-Byram Drought Index alone is not a good indicator for fire activity."
Chan et al. (2004)

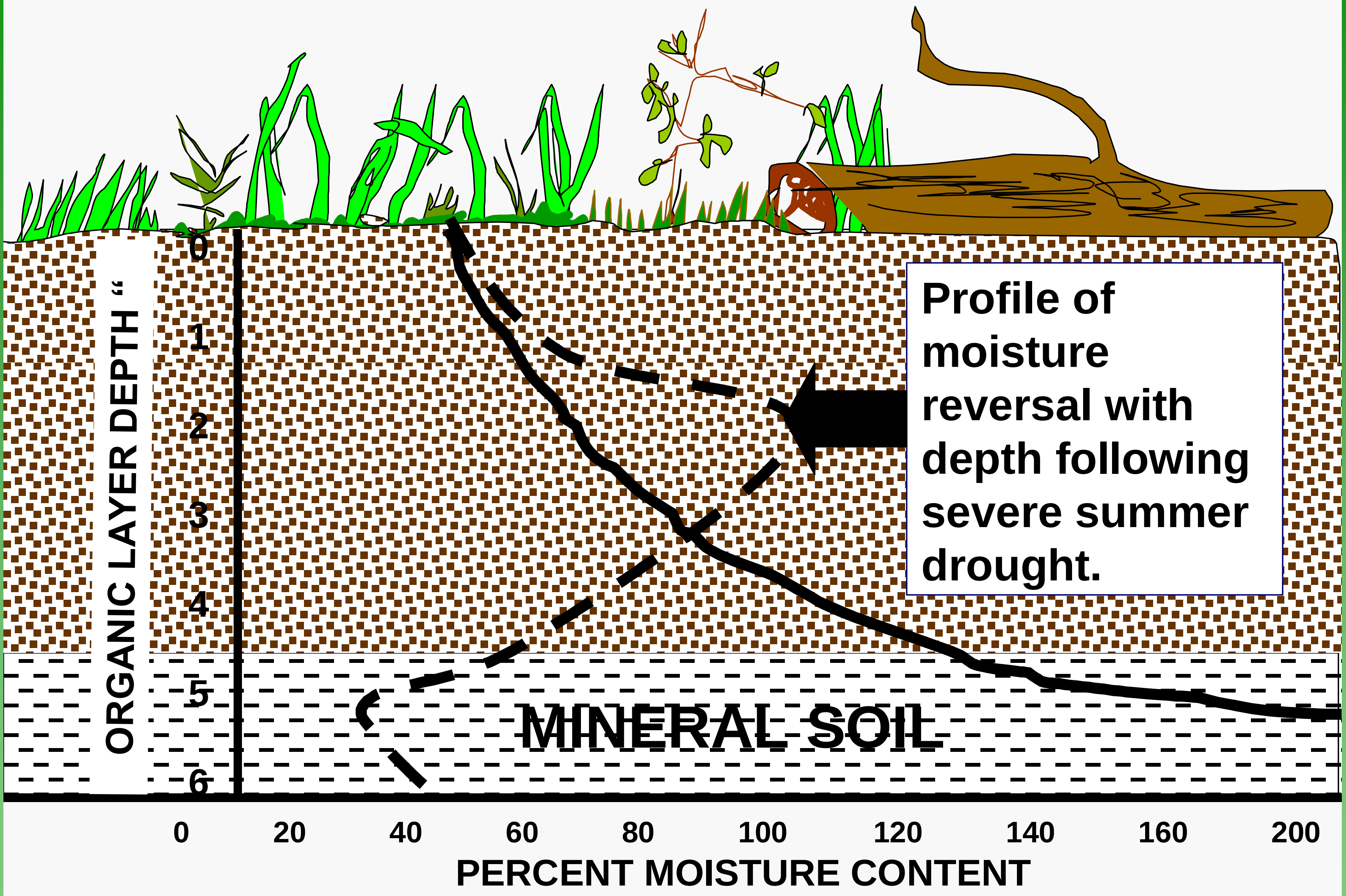
***Fire Management Today* – Spring 2004**

Peshtigo Fire Complex, Wisconsin October 8, 1871

Keetch-Byram Drought Index: 300*

*Haines et al. (1976)
USDA Forest Service Res. Pap. NC-131


Moisture content increasing with depth under "normal" conditions.
ORGANIC LAYER DEPTH "
0
1
2
3
4
5
6
MINERAL SOIL
0
20
40
60
80
100
120
140
160
200
PERCENT MOISTURE CONTENT



Profile of moisture reversal with depth following severe summer drought.
ORGANIC LAYER DEPTH "
0
1
2
3
4
5
6
MINERAL SOIL
0
20
40
60
80
100
120
140
160
200
PERCENT MOISTURE CONTENT

Canadian Forest Fire Danger Rating System: Analyses of Drought Effects on Fire Potential

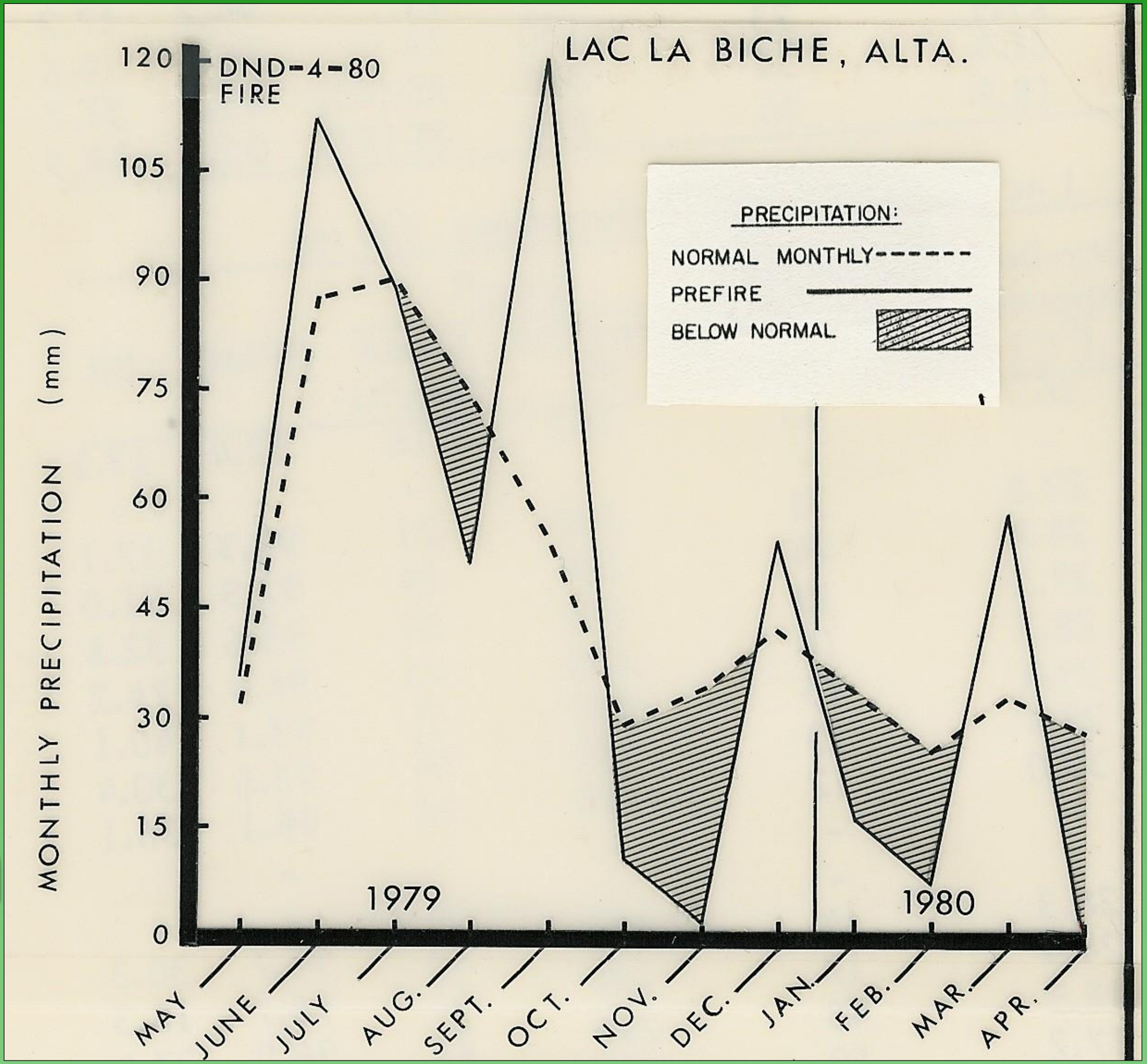
Drought Code (DC)	Buildup Index (BUI)	Fire Weather Index (FWI)*	Head Fire ROS (m/min)	Head Fire Intensity (kW/m)
100	40	20	11.6	8906
200	53	23	12.9	11 739
300	60	25	13.4	13 089
400	64	25	13.7	13 812
500	67	26	13.9	14 332
600	68	26	13.9	14 502
700	70	27	14.0	14 835
800	71	27	14.1	14 999

*Very High fire danger class in Alberta (FWI 19-29).

Assume: Fine Fuel Moisture Code (FFMC) 89, Duff Moisture Code (DMC) 40, 10-m Open Wind 20 km/h, Level Terrain, and Boreal Spruce Stand in mid July.

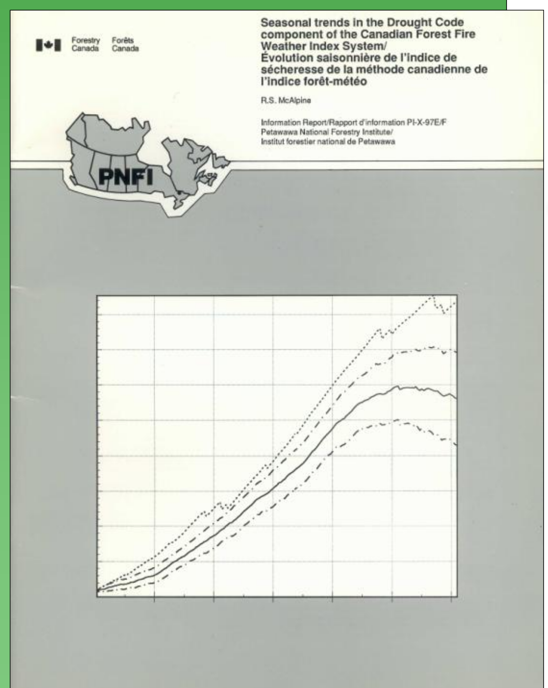
Thought #2:

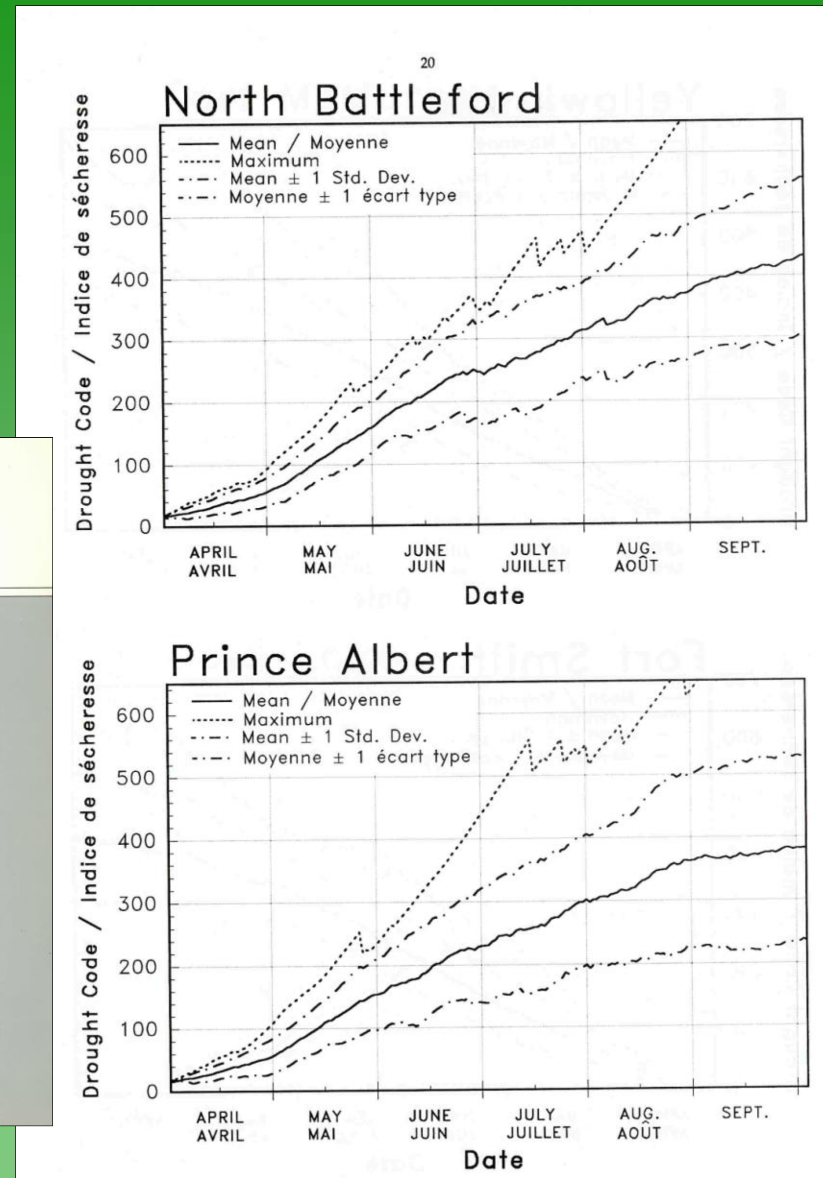
Construct Simple Time Series of Monthly Precipitation Departures from Normal for Long-term Weather Stations



Thought #3:

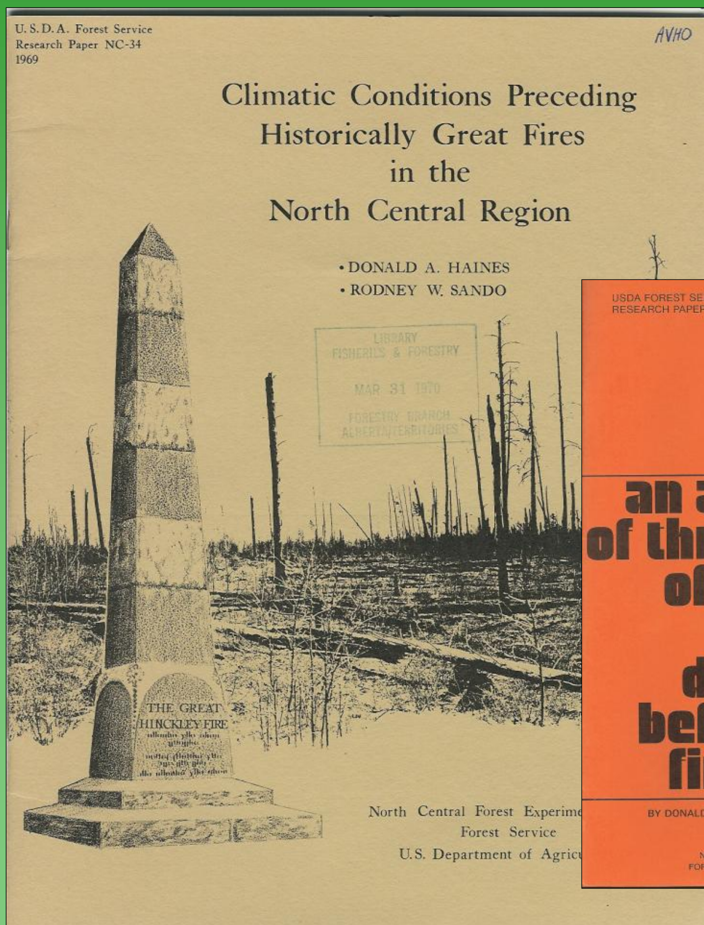
Develop "Fire – Drought" Index Climatologies for Long-term Weather Stations

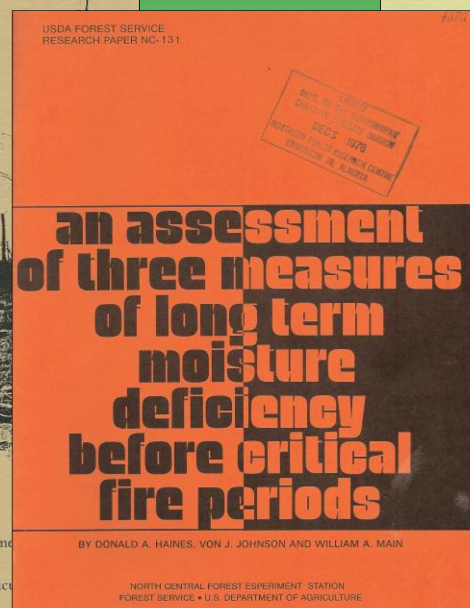


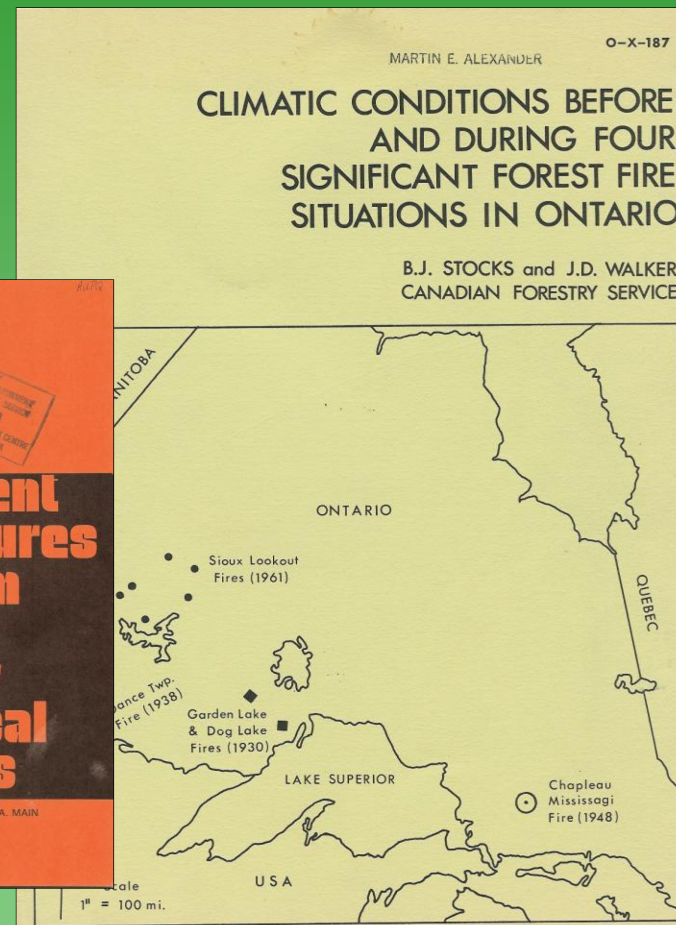


Thought #4:

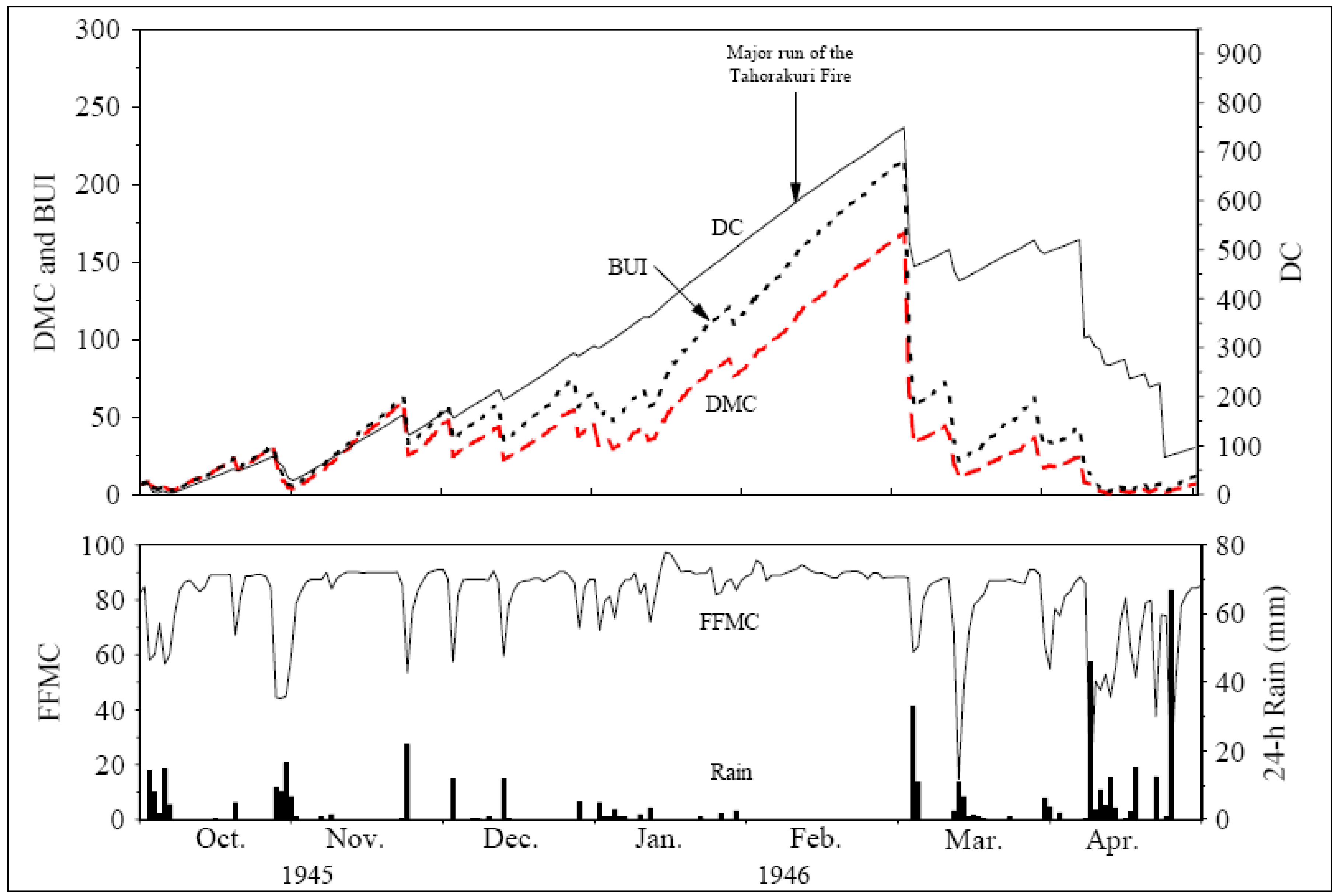
Retrospective Look at Major Historical Events



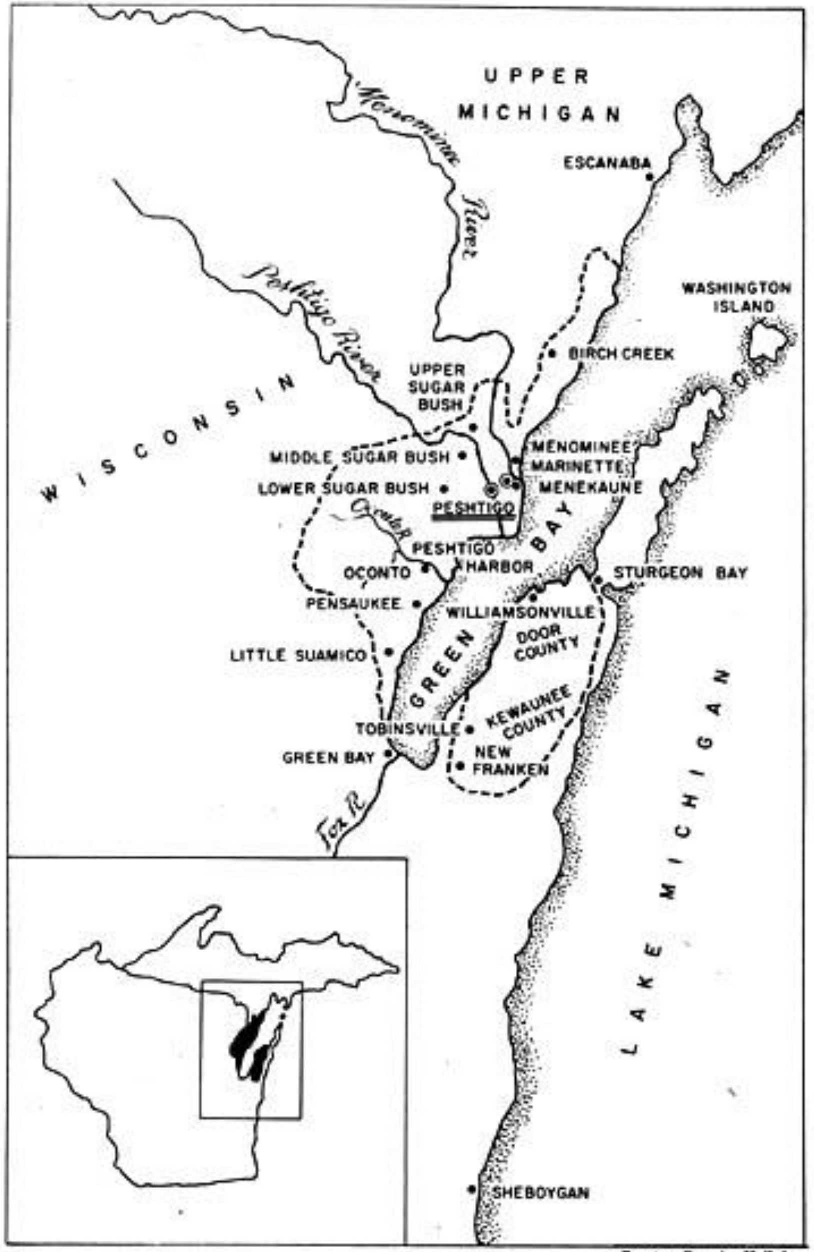




1945-46 Fire Season – New Zealand



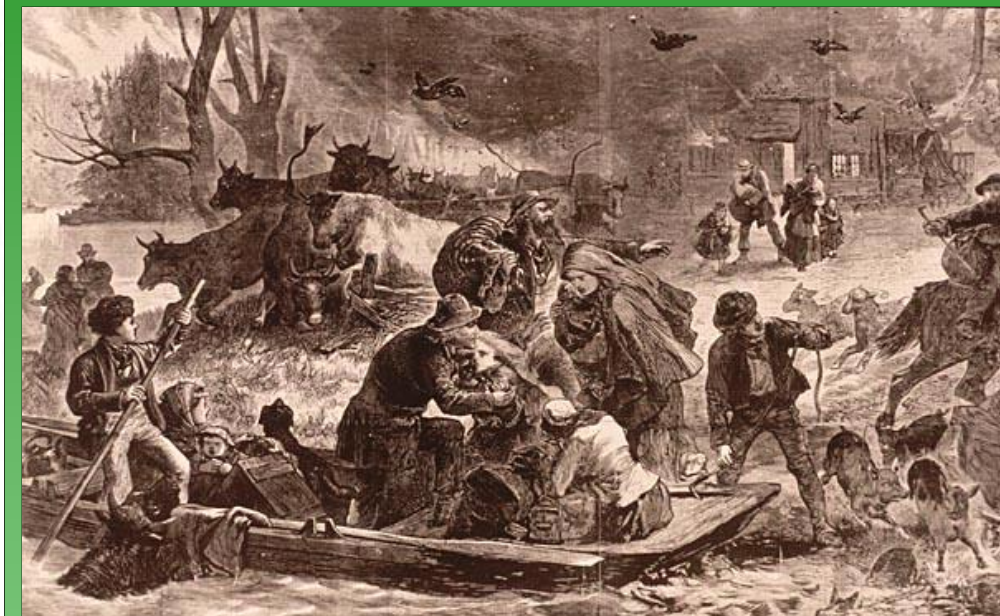
1947 Fire Season - Portland, Maine



Courtesy Prentice-Hall, Inc.

Map adapted from Tilton's Great Fires in Wisconsin, and used in Robert Wells' Fire at Peshtigo to illustrate the burnt district in Wisconsin and Michigan. The dotted lines indicate the approximate extent of the devastation, as do the blackened areas in the insert.

Peshtigo Fire Complex, Wisconsin October 8, 1871

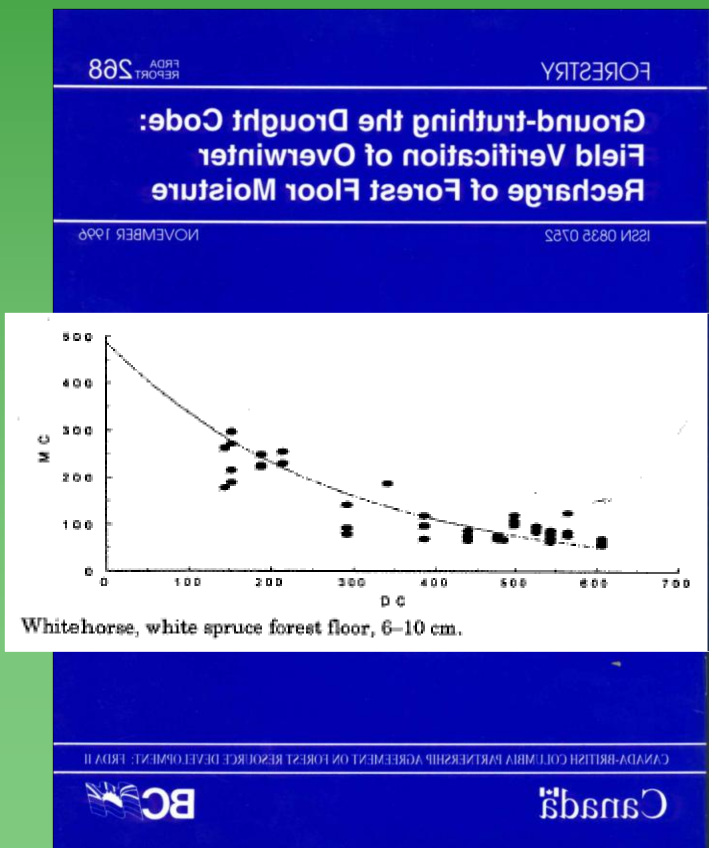


Palmer Drought Severity Index: -3.8 (Severe)*

*Haines et al. (1976)
USDA Forest Service Res. Pap. NC-131

Thought #5:

Establish Network of "Fire-Drought" Monitoring Sites



Vision:

- Weather observations
- Upland and lowland sites in close proximity to one another
- Fuel moisture sampling and water level measurements (wells and natural conditions in wetlands and surface water bodies)

Precedents

Establishment of benchmark sites for the verification of overwinter recharge of forest floor moisture in Alberta.

Preliminary Report

June 30, 2000

Prepared for

Alberta Lands and Forest Service
Forest Protection Division
Great West Life Building
9920 108th Street
Edmonton, Alberta   T5K 2M4

Prepared by

EMBER

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Field verification of forest floor moisture contents on benchmark sites in Alberta (May 2000)

June 30, 2000

Prepared for

Alberta Land and Forest Service
Forest Protection Division
Great West Life Building
9920 108th Street
Edmonton, Alberta   T5K 2M4

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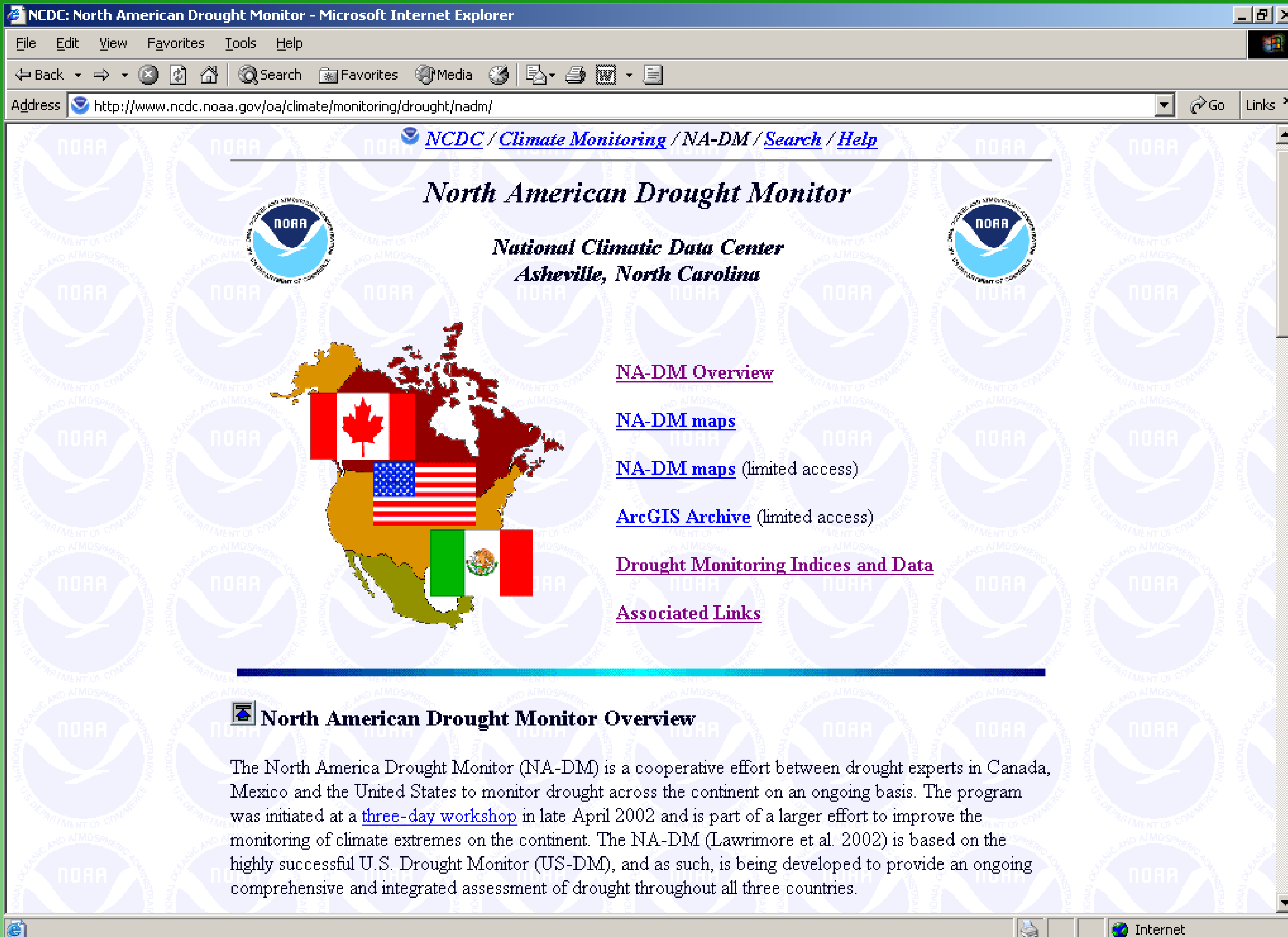
Similar work in the Yukon Territory

Such an initiative should be coordinated with NA-DM



Thought #6:

Examine the Suitability of Existing Long-term Drought Indices (or Construct a New One) for Gauging the Impacts of Multi-year Drought Episodes on Wildland Fire Suppression Activities

Possible Candidates:

- Percent of Normal Precipitation
- Standardized Precipitation Index (McKee et al. 1993)
- Palmer Drought Severity Index (Palmer 1965)
- Surface Water Supply Index (Shafer & Dezman 1982)
- Basic Drought Index (Van Wagner 1985)
- Ichnusa Fire Index (Spano et al. 2003)

Key Considerations:

- Index scale and units
- Simple to calculate
- Meaningful interpretation
- May require multiple indexes

Thought #7:

Future Case Study Documentation Must Have Better Measures of Ground or Sub-surface Fire Persistence and Mop-up Difficulty

THE END – THANK YOU

Any questions or comments?